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PROGNOSIS IN FEMORAL NECK FRACTURE

A clinical, radiographic and radionuclide investigation

Lund 1983

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From the University Department of Orthopaedics in Lund, Sweden

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To my wife Lena
and our children
Anna, Carl and Jacob

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This work is based on the following papers:

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I Brümmer, R.: Natural course in nailed fractures of the femoral neck. A five-year prospective investigation. (Will be published)	33
II Brümmer, R., Hansson, L.I., Mortensson, W.: A radiographic five-year follow-up of femoral neck fractures. Acta Orthop Scand (Accepted for publication).	47
III Brümmer, R., Hansson, L.I., Mortensson, W., Sjöstrand, L.O.: ⁸⁵ Sr-scintimetry in femoral neck fracture. Arch Orthop Traum Surg 101: 47-51, 1982.	61

I INTRODUCTION

The risk for necrosis of the femoral head following intracapsular fracture of the hip is generally regarded as 50 per cent or higher (Jensen and Tøndevold 1979). Therefore primary arthroplasty is often done in displaced fractures in elderly patients (Hinchey and Day 1964, Hunter 1980). However, the diagnosis of complications associated with avascularity of the femoral head can be done in the preradiographic stage with the aid of radionuclide scintimetry (Asnis et al 1976, Bauer et al 1980, Strömqvist 1983). An alternative strategy would therefore be to nail all or most fractures of the femoral neck and then do a secondary arthroplasty in patients who have clinical symptoms of impending failure. The advantage of this strategy as compared to primary arthroplasty is that one avoids an extensive operation in those who would have had uncomplicated healing or who are destined to die from generalized disease before the necrosis has caused functional disability.

This investigation was planned to follow the development of posttraumatic necrosis of the femoral head radiographically and scintimetrically in a clinically and sociologically well defined and representative material of patients with hip fracture.

II MATERIAL AND METHODS

The material for this prospective investigation comprised 40 patients with intracapsular subcapital or transcervical femoral fractures admitted to the Department of Orthopaedic Surgery, University Hospital in Lund during the period May 1975 - May 1976. Patients unable to co-operate or who did not have a radiographically normal contralateral hip were not selected for the investigation.

The mean age of the patients was 73 (38-93) years; all but six patients were older than 60 years (Table 1). Eight of the 40 patients died within five years.

The fractures were operated as soon as the patient's general condition and the resources of the surgical unit permitted, i.e. usually within 24-48 hours. Before the operation, unstable fractures were treated with traction through the tibial tuberosity. The operation was performed under image intensifier control, and the Rydell (1964) four-flanged nail was used. The patients were encouraged to walk with full weight-bearing the day after the operation (Ceder 1980).

Clinical data

The patients were followed-up clinically at four and six months, at one and two years, and they were interviewed five years after the fracture.

The clinical criteria were: pain at rest, pain on weight-bearing and walking capacity. The walking capacity was characterized as incapacity (walking less than ten metres), poor (walking with two quatraps or sticks), fair (walking with one stick and/or with a limp), or good (unrestricted walking ability). The mobility of the hip was recorded. The results were evaluated in relation to age, clinical status, and living situation.

Radiographic data

On admission, the hips were radiographed in antero-posterior and lateral projections and the fractures were classified according to Garden's (1961)

system modified according to Graham and Wood (1976). A distinction was made between fractures with minor displacement (Garden I and II, 9 cases) and those with major displacement (Garden III and IV, 31 cases). The fractures were classified as healing without complications (13 cases) when there were no changes diagnostic for necrosis or non-union, and as non-union/pseudarthrosis (5 cases) when the fracture was visible with sclerotic bone on one or both sides. Necrosis (22 cases) was considered present when compression of the loadbearing surface and subchondral fracture was observed. The diagnosis was confirmed histologically in those patients who had a secondary arthroplasty. In certain cases the patients were followed radiographically for three, four and even five years if necrosis had not been visible in earlier examinations.

Scintimetric data

The scintimetry method used in this investigation was described by Bauer and Wendeberg (1959) and Sjöstrand (1974). ^{85}Sr scintimetry was performed two weeks and four months after the fracture. With the aid of the radiogram the scintimetry pattern of the femoral head was divided into four sectors (Fig 1), the upper (I), medial (II), lower (III) and the lateral (IV). Within these sectors the mean counting rates were calculated. The mean value of the acetabular area was obtained from eight pixels. Finally, a 25 mm wide area around the nail was identified and the activity values in the trochanter (T), neck (Co) and head (Ca) areas were recorded (Fig 2).

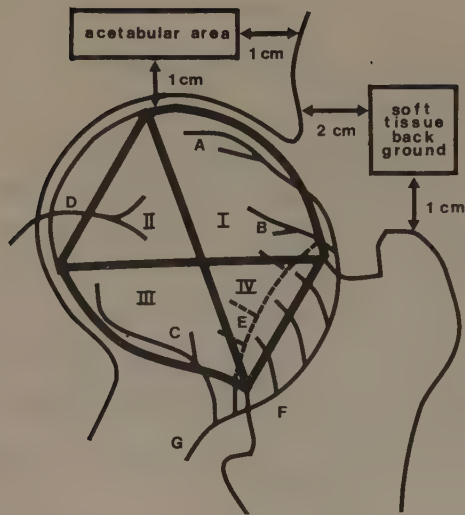


Fig 1. Blood supply to the femoral head in the adult according to Trueta and Harrison (1953). Sevvitt and Thompson (1956), Catto (1976), Graham and Wood (1976), Crock (1980). A. lateral epiphysial artery; B. superior metaphysial artery; C. inferior metaphysial artery; D. foveal (medial epiphysial) artery; E. medial femoral circumflex artery; F. lateral femoral circumflex artery; G. profunda femoris artery. The areas of interest for ^{85}Sr activity measurements have been superimposed on the outline of the radio-graph.

The mean counting rates within the areas of interest were corrected for background measured over soft tissue lateral to the hip joint. The room background activity was about 4 counts/10 sec and the soft tissue back-ground was about 6 counts/10 sec. In order to account for individual variations in the metabolism of strontium the ^{85}Sr activity values recorded over the fractured hips were expressed as ratios relative to the values recorded over identical areas of interest of the contralateral intact hip. Under the conditions specified by Bauer and Wendeberg (1959) these ratios were interpreted as relative rates of bone formation.

Statistical evaluation

The Student's t-test was used, and the levels of significance were indicated as follows:

-	= insignificant	$p > 0.05$
*	= almost significant	$0.05 > p > 0.01$
**	= significant	$0.01 > p > 0.001$
***	= highly significant	$p < 0.001$

III RESULTS

Intact hips

The distribution of activity in the upper femur of the intact hips was markedly uneven as recorded at two weeks in 29 cases and at four months in all 40 cases. The medial head sector had the highest activity and the trochanter area had the lowest (Fig 2). Highly significant differences were found between the medial and lateral sectors of the femoral head, between the head and neck areas, and between the head and trochanter areas. In general the activity was somewhat higher in the femur at four months than at two weeks except in the acetabulum.

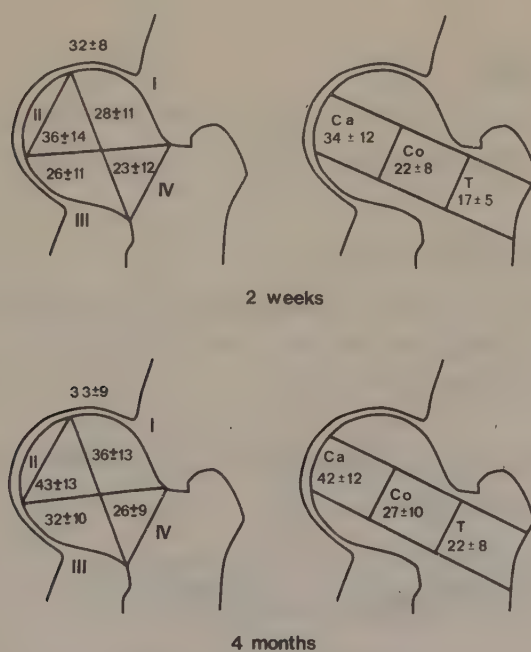


Fig 2. Mean ^{85}Sr activity in different sectors of 29 intact hips 2 weeks and 4 months after fracture

Table 1. Classification of the fractures, the fate and age distribution

Fracture type	Uncompl healing	Necrosis	Non-union	Total	Mean age (range)
Minor displacement	6	3	0	9	73 (52-87)
Major displacement	7	19	5	31	73 (38-93)
Total	13	22	5	40	73 (38-93)

Uncomplicated healing

In cases with minor displacement 6/9 healed without complication but in cases with major displacement only 7/31 healed uncomplicatedly (Table 1)

1. Clinical examination (Table 2)

It was not possible to identify uncomplicated healing cases by clinical examination as pain at rest and pain on weight-bearing were present even in cases with uncomplicated healing.

The walking capacity was influenced by the patient's age rather than by the fate of the femoral head.

Table 2. Clinical investigation of 13 femoral neck fractures with uncomplicated healing

Frequency of	4 months n=12	6 months n=12	1 year n=12	2 years n=8
Pain at rest	0	2	1	3
Pain on weight-bearing	1	4	1	1
Poor walking capacity	3	3	2	0
Internal rotation 15° or less	2	3	5	5
Flexion 90° or less	3	1	2	5

2. Radiographic examination (Figs 3 and 4)

In uncomplicated healing cases compression in the fracture area and sclerosis in the femoral head was less frequent than in necrosis and pseudarthrosis cases.

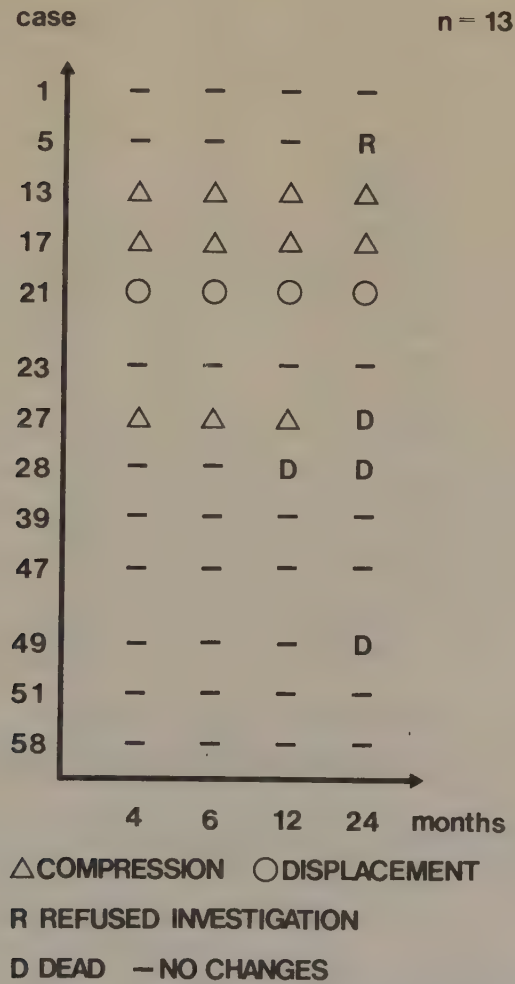


Fig 3. Radiographic changes in the femoral neck in 13 cases with uncomplicated healing

In five out of 13 uncomplicated healing cases no radiographic changes at all were present in the femoral neck or in the head; the presence of radiographic changes was thus compatible with uncomplicated healing.

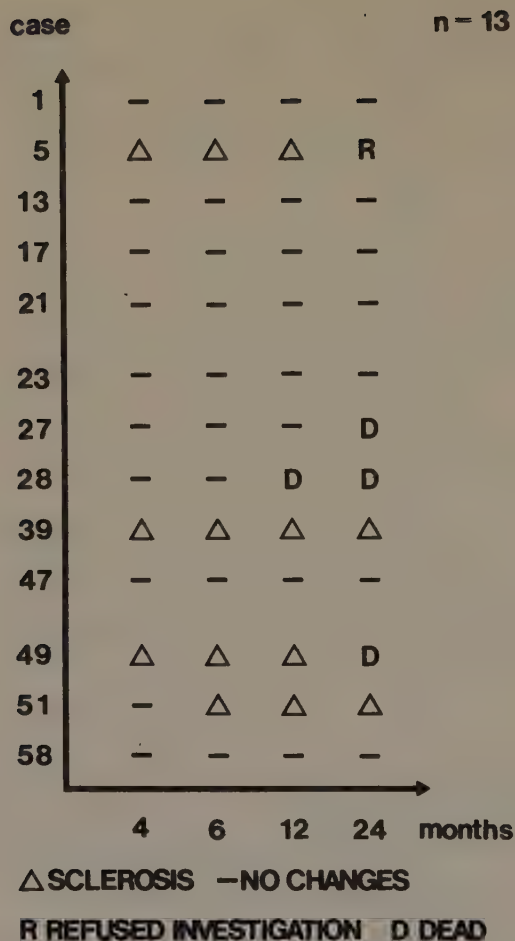


Fig 4. Radiographic changes in the femoral head in 13 cases with uncomplicated healing

3. Scintimetry

As compared to the intact hips the scintimetry values of hips with fresh fractures were generally increased by about 50 per cent except the acetabular area, which did not show increased activity. Two weeks after fracture the ^{85}Sr activity values could not be used to predict the healing course of the fracture (Table 3).

Table 3. ^{85}Sr activity ratio 2 weeks after femoral neck fracture

		Areas of interest				Ca	Co	T
		I	II	III	IV			
Uncomplicated healing n = 10	$\bar{x}$	1.3	1.2	1.6	2.0	1.2	2.0	1.9
	s	0.3	0.3	0.5	0.8	0.3	0.6	0.7
Necrosis n = 14	$\bar{x}$	1.2	1.4	1.8	1.9	1.3	1.8	1.7
	s	0.6	1.8	1.9	1.0	1.2	0.7	0.5
Non-union n = 5	$\bar{x}$	1.4	1.0	1.4	2.2	1.1	2.0	2.0
	s	0.4	0.3	0.5	0.8	0.3	0.4	0.4

In contrast to the negative findings early after fracture, scintimetry four months after the fracture showed that the biological response could be correlated to initial displacement and to the fate of the fracture. The activity ratios at four months were thus higher in fractures with major displacement than in those with minor displacement. This was most obvious in the lateral sector IV and the T area (Table 4).

Table 4. ^{85}Sr activity ratio in uncomplicated healing cases 4 months after fracture

Fractures with minor displacement compared with fractures with major displacement

Displacement		Areas of interest				Ca	Co	T
		I	II	III	IV			
Minor n = 6	$\bar{x}$	1.9	2.2	3.0	2.9	2.1	3.0	2.0
	s	0.5	0.8	1.0	0.6	0.9	0.7	0.5
Major n = 7	$\bar{x}$	2.9*	2.5 ⁽⁻⁾	4.0 ⁽⁻⁾	4.7**	2.6 ⁽⁻⁾	4.9*	4.0***
	s	1.0	1.1	2.0	1.1	0.9	1.4	0.8

Necrosis

Necrosis developed in three of nine fractures with minor displacement and in 19 of 31 with major displacement.

1. Clinical examination

Pain at rest and pain on weight-bearing were more frequent in necrosis cases than in uncomplicated healing, but the difference was not sufficient to be diagnostic for necrosis.

The occurrence of poor walking capacity was approximately the same in cases with necrosis as in cases with uncomplicated healing. Reduced mobility was almost the same in uncomplicated healing and necrosis cases.

Clinical examinations of the patients after cervical fractures were thus of little diagnostic value for diagnosis of necrosis (Table 5).

Table 5. Clinical investigation of 22 femoral neck fractures with necrosis

Frequency of	4 months n=22	6 months n=21	1 year n=20	2 years n=18
Pain at rest	3	3	5	7
Pain on weight-bearing	10	11	9	13
Poor walking capacity	5	5	2	3
Internal rotation 15° or less	8	8	14	13
Flexion 90° or less	6	5	6	13

2. Radiographic examination

Radiographic changes in the femoral neck and head in necrosis were late, and changes, such as compression in the fracture area and sclerosis in the femoral head were not conclusive. However, once subchondral fracture and segmental collapse had developed, an irreversible injury of the femoral head was documented.

Only in one case did segmental collapse appear already at four months; it probably was due to nail penetration and it did not change later on. In all other cases the irreversible change of the articular surface took place after the proof of necrosis by ^{85}Sr -scintimetry at four months (Figs 5 and 6).

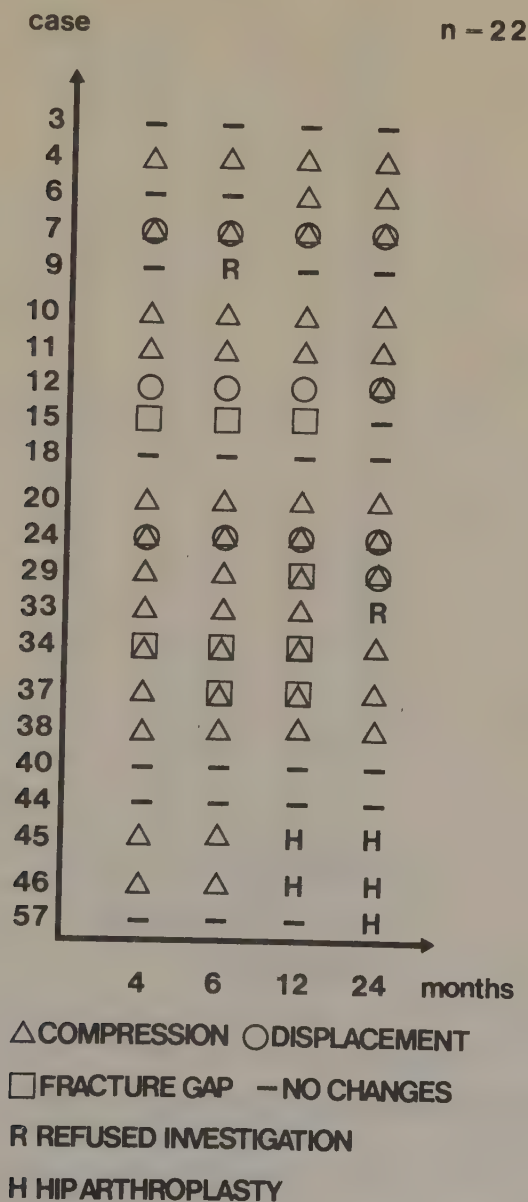


Fig 5. Radiographic changes in the femoral neck in 22 necrosis cases

case

n - 22

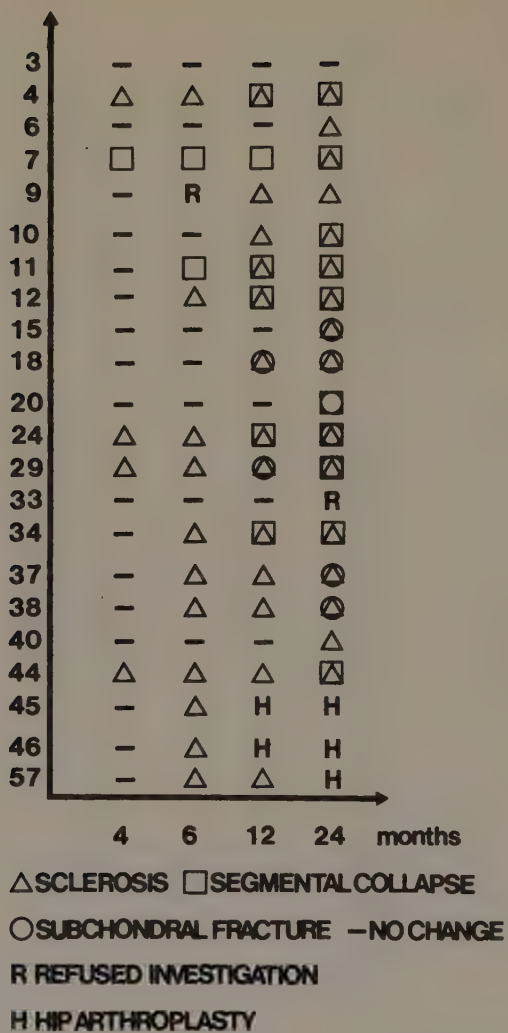


Fig 6. Radiographic changes in the femoral head in 22 necrosis cases

3. Scintimetry

Two weeks after the fracture the ⁸⁵Sr activity ratio was inconclusive in necrosis cases (Table 3). However, four months after the fracture the ⁸⁵Sr activity was significantly higher in cases with necrosis compared with uncomplicated healing cases. In fractures with minor displacement, cases with development of necrosis had a significantly higher activity in sector I, and in the Co- and T-areas. The most intense activity was located in the fracture region (IV). In necrosis cases with major displacement the ⁸⁵Sr activity increased in a specific way only in the sector IV.

Table 6. ⁸⁵Sr-activity ratio in necrosis cases four months after fracture
Activity data in necrosis cases compared with uncomplicated healing fractures of the same category of displacement.

		Areas of interest						
Displacement		I	II	III	IV	Ca	Co	T
Minor	$\bar{x}$	3.1**	3.7*	4.4 ⁽⁻⁾	5.9***	3.2 ⁽⁻⁾	5.5**	4.9**
n = 3	s	0.3	0.5	0.8	0.8	0.5	0.7	1.8
Major	$\bar{x}$	3.0 ⁽⁻⁾	2.6 ⁽⁻⁾	4.4 ⁽⁻⁾	6.5**	2.9 ⁽⁻⁾	6.6 ⁽⁻⁾	5.2 ⁽⁻⁾
n = 10	s	1.0	1.0	1.3	1.3	1.0	2.1	1.9

Pseudarthrosis/non-union

Non-union occurred only in cases with major displacement.

1. Clinical examination

Clinical signs such as pain at rest and pain on weight-bearing were most frequent and severe in non-union cases. Even walking capacity and mobility in the affected hip were worst in non-union (Table 7). For this reason hip replacement was most frequent in this group and had been carried out in 3/5 cases within the first year. Even in the two other cases hip arthroplasty was indicated, but one patient, an 87-year-old woman, was in a too poor general condition, and another, a 78 year-old woman, preferred to live with her handicap.

Table 7. Clinical investigation of five femoral neck fractures with non-union

Frequency of	4 months n=5	6 months n=4	1 year n=2	2 years n=2
Pain at rest	2	2	0	0
Pain on weight-bearing	3	2	1	1
Poor walking capacity	3	3	1	0
Internal rotation 15 ⁰ or less	3	2	2	2
Flexion 90 ⁰ or less	3	2	2	2

2. Radiographic examination

Compression, displacement and/or a fracture gap appeared early in the femoral neck. Case 52 received hip replacement within one year in spite of negative radiography (Figs 7 and 8).

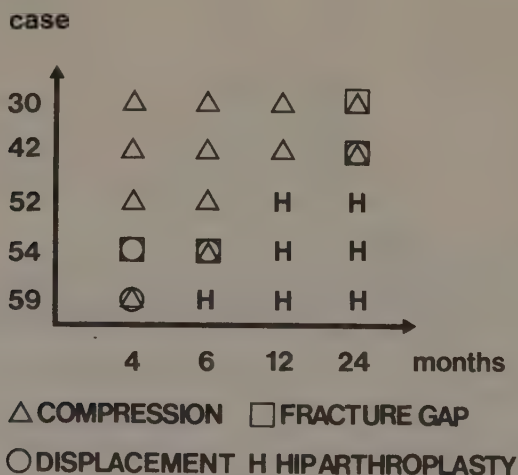


Fig 7. Radiographic changes in the fracture area of five femoral neck fractures with pseudarthrosis/non-union

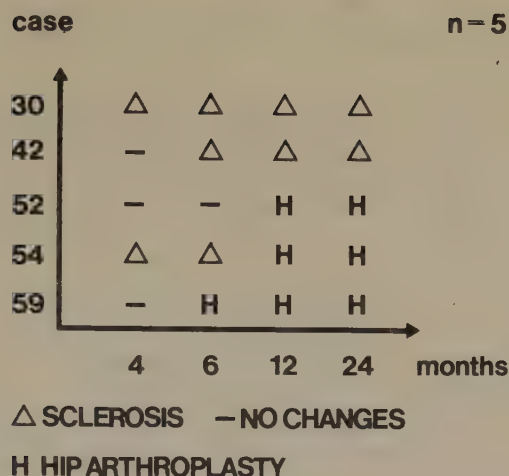


Fig 8. Radiographic changes in the femoral head of five femoral neck fractures with non-union.

3. Scintimetry

⁸⁵Sr scintimetry was inconclusive two weeks after fracture (Table 3). At four months scintimetry showed low activity in the trochanter area and especially in Sector IV (Table 8).

Table 8. ⁸⁵Sr activity ratio at 4 months in femoral neck fractures with pseudarthrosis/non-union

Activity data in non-union cases compared with uncomplicated healing fractures of the same category of displacement.

Displacement		Areas of interest				Ca	Co	T
		I	II	III	IV			
Major	$\bar{x}$	1.9 ⁽⁻⁾	1.5 ⁽⁻⁾	2.0 ⁽⁻⁾	3.0**	1.9 ⁽⁻⁾	3.1*	2.8*
n = 5	s	0.5	0.3	0.5	0.5	0.4	0.4	0.6

Living situation

The living situation had changed in 15 of 40 patients (Table 9). Four patients had moved from their own home to a home for the aged (mean age 84 years 1980) and three to a nursing home (mean age 84 years 1980). Eight patients had died (mean age 83 years) (Table 10). These changes in the living situation seemed to be adequately age-related.

Table 9. The living situation 1975-1976 and 1980 of 40 patients with cervical fractures

Case no	Age at fracture	Sex	Garden type	Living alone	Home 1975/76	Home 1980	Uncompl healing	Compli- cation	Nail extr.	Hip arthro- plasty
1	80	F	III	+	2	2	+			
3	75	F	III		1	1		N		
4	79	F	IV	+	1	1		N	+	Demi/2 y
5	72	F	IV		1	1	+			
6	76	F	IV		1	1		N		
7	85	F	III		2	dead		N		
9	78	M	III		1	1		N		
10	75	F	IV		1	1		N		
11	82	F	I	+	1	1		N	+	Total/2 y
12	78	F	I	+	1	dead		N		
13	87	F	I		3	dead	+			
15	73	M	III		1	1		N		
17	62	F	IV	+	1	1	+			
18	52	F	I	+	1	1		N	+	
20	87	F	IV		1	3		N		
21	79	F	IV		1	2	+			
23	75	F	I		1	2	+		+	
24	93	F	III		2	dead		N		
27	85	F	III		3	dead	+			
28	78	M	IV		3	dead	+			
29	71	F	III	+	1	1		N	+	Total/3 y
30	85	F	III		3	dead		P		
33	81	M	III	+	1	3		N		
34	54	F	IV	+	1	1		N		
37	81	F	IV		3	3		N		
38	68	M	III		1	2		N		
39	66	F	I		1	1	+			
40	54	F	IV	+	1	1		N		
42	77	F	IV	+	1	1		P		
44	38	M	III		1	1		N	+	
45	55	F	III		1	1		N		
46	73	F	III		1	1		N	+	Total/8 m
47	64	F	IV	+	1	1	+		+	Total/10 m
49	73	F	II	+	1	dead	+			
51	72	M	II	+	1	3	+			
52	75	F	III	+	1	1		P	+	Total/9 m
54	74	M	III		1	1		P	+	Demi/7 m
57	55	F	III	+	1	1		N	+	Total/2 y
58	76	F	II		3	3	+			
59	92	F	IV	+	1	2		P	+	Demi/5 m

Living stage: 1 = at home
2 = at home for the aged
3 = at nursing home

Complication: N = necrosis, P = pseudarthrosis/non union

Table 10. Social outcome 5 years following femoral neck fracture

At fracture	n	Five years after fracture			
		Home	Home for aged	Nursing home	Dead
Home	31	22	4	3	2
Home for aged	3		1		2
Nursing home	6			2	4
	40	22	5	5	8

In nine of the patients, i.e. in nine of 27 cases of necrosis or non-union a salvage arthroplasty was performed. All of these lived in their own home at the time of fracture and all but one were living at home five years later. Six of those who had hip replacement were living alone in 1975 and in 1980. Three were living with someone in 1975 but one lost her partner the year after fracture.

IV DISCUSSION

The prognosis after fracture of the hip is not good. In an unselected material the majority of the patients are octogenarians, many suffer from severe neurologic or cardiovascular disease (Ceder et al 1980, Abdon and Nilsson 1980), and 20-25 per cent are dead within a year (Alffram 1964, Ceder et al 1979). In the survivors, rehabilitation is threatened by complications associated with disturbed fracture healing; in displaced intra-capsular fractures, as many as 50 per cent are destined for early problems due to non-healing or late segmental collapse of the femoral head. With this general background it is logical that improved methods for hip arthroplasty have led an increasing number of orthopaedic surgeons to recommend this procedure as primary treatment in fresh fractures of the femoral neck (Hinchey and Day 1964, Søreide et al 1980, Sonne-Holm et al 1982).

However, compared to nailing of the fracture a hip arthroplasty is costly and strenuous to the patient, and it has no advantage for patients destined to early death or to those who would have healed their fractures uneventfully following primary nailing. As recent literature does not contain any long-term studies of the prognosis following primary nailing, the material presented here will be discussed in terms of the choice of treatment of fresh fractures of the femoral neck.

Protagonists of primary arthroplasty usually recommend this procedure for patients above age 60 with displaced fractures. With these criteria primary arthroplasty would have been performed in twenty-eight cases of our displaced fractures; three displaced fractures in patients under 60 and nine undisplaced fractures would have had primary nailing. How many of these would have been unnecessary because of early death or uneventful healing? Let us first consider two criteria for evaluation of the therapy, immediate mobilization and the five-year-status.

If the choice of procedure were based on the capability of the patients to bear full weight on the hip the day after the operation no primary arthroplasty would have been indicated; in this material all the patients had a stable fracture after nailing and were able to walk immediately after the operation.

In terms of the five year prognosis, a primary arthroplasty would have been retrospectively unrewarding for eight patients who died and seven who had displaced fractures which healed uneventfully. Furthermore, the indications for a primary arthroplasty would have been rather vague in the majority of the osteonecrosis cases; 16 of 22 osteonecrosis cases had not been subjected to arthroplasty five years after the fracture. In the five non-unions on the other hand, an arthroplasty was performed in three within one year of the fracture, one died early, and one who is living at home has preferred not to have a secondary procedure. Even if we estimate that one half of the osteonecrosis cases which have not yet had a secondary procedure would have been better off with a primary procedure, as many as 22 of 31 displaced fractures would have had an unrewarding primary arthroplasty. Among the undisplaced fractures however, three developed osteonecrosis; with the criteria discussed here, two of those also had an unrewarding primary nailing of the fracture.

At this stage of the discussion it would seem that generally accepted rules for the choice of primary arthroplasty in fresh intracapsular fracture of the femoral neck are highly imprecise; two thirds of the patients recommended this procedure derive little or no benefit from this choice.

The lack of precision in deciding the prognosis after a fracture of the femoral neck is of course well known, and this problem has been addressed by a large number of investigators over the last thirty years. Most of the methods used for prediction of the vascularity of the femoral head have been invasive, time consuming and/or imprecise (Hulth 1965). The only practical avenue that still remains seems to be the use of bone seeking γ -emitting radionuclides, notably ^{85}Sr (Bauer and Ray 1958, Cameron 1969), ^{18}F (Riggins et al, 1973) and especially technetium labelled phosphonates (Subramanian et al 1971). This investigation shows that ^{85}Sr , for reasons unknown, does not permit a diagnosis of non-vascularity in fresh fractures of the femoral head, and like ^{18}F the method is impractical as compared to technetium labelled phosphonates. D'Ambrosia et al (1978) and Bauer and Hansson and their co-workers (Strömqvist 1983) have now shown that this technique permits a rapid and precise diagnosis of femoral head avascularity, suitable for a preoperative choice between nailing and arthroplasty in fractures of the femoral neck.

However, this investigation does not support the choice of a primary arthroplasty even if a precise preoperative diagnosis of femoral head avascularity can be done. Following primary nailing of the fracture only a minority had such severe complications, notably non-union, that an arthroplasty was required to maintain function. The majority of the patients with complications associated with avascularity of the femoral head, notably segmental collapse, had rather mild symptoms; the decision whether or not to have an arthroplasty seemed to be based more on social conditions than on the function of the hip. Finally, even though the nature of this long-term investigation discriminated particularly fragile patients from inclusion, several patients were dead before they would have had any benefit from a primary arthroplasty. In this material the five non-unions were all diagnosed within one year, one of those died and the three secondary arthroplasties were all performed within nine months of the fracture. By contrast half of the necrosis cases had a radiographic diagnosis after more than one year (Table 11), and four of the six secondary arthroplasties were performed two years or more after the fracture. When the incidence and time table of the development of hip problems, associated with the fracture, are compared with the 20-30 per cent one-year mortality in unselected materials of hip fracture, the case for primary arthroplasty in this condition seems weak indeed.

Table 11. Time of radiographic diagnosis: necrosis (N) and pseudarthrosis/non-union (P) after 40 femoral neck fractures

*cases with negative radiographic findings

	Within 1 year	1-2 years	2-3 years	3-4 years	4-5 years
Case no	4 N	10 N	40 N	3 N	6 N
	7 N	12 N		33 N	
	9 N	15 N			
	11 N	20 N			
	18 N	34 N			
	24 N	37 N			
	29 N	38 N			
	30 P	44 N			
	42 P	57 N			
	45 N*				
	46 N*				
	52 P*				
	54 P				
	59 P				
Number	14	9	1	2	1
Percentage of the material	35 %	58 %	60 %	65 %	68 %

The strategy for treatment of intracapsular fracture of the femoral neck applied here does not end with the choice of nailing as the primary procedure. Rather, the technical handling of the hip problem is dovetailed to programs for mobilisation and rehabilitation developed over a 10-year period of trial and error (Ceder 1981). After five years two thirds of the patients in this material who suffered their fracture while living at home were still at home, and the number of patients under institutional care was unchanged (Table 10). Valid comparisons of strategies and tactics for handling of the extremely complicated problem of the fractured hip in the aged should include information on the long-term social outcome.

V GENERAL SUMMARY

The purpose of this investigation was to study the natural history of the intracapsular fracture of the femoral neck following primary nailing. From its inception the investigation was planned to correlate the clinical, radiographic and metabolic development of complications to the fracture for five years.

Forty patients with femoral neck fractures were investigated by clinical and radiographic examinations and ^{85}Sr -scintimetry. The mean age was 73 years; four patients were younger than 55 years. Out of nine cases with minor displacement six healed without complications. Out of 31 cases with major displacement 19 developed necrosis and five non-union. Eight patients died, and nine had secondary arthroplasties.

Clinical observations: Increasing weight-bearing pain was an early sign of necrosis or non-union and it was the main indication for secondary arthroplasty. However, pain on weight-bearing was not always incapacitating, and five patients with necrosis had no complaints at all. Walking capacity improved during the first year after fracture in uncomplicated healing just as well as in necrosis cases; after one year the situation was stationary. The mobility in the fractured hip was diminishing in uncomplicated healing as well as in necrosis cases.

Radiographic investigations up to five years after fracture showed that changes which have been interpreted to indicate necrosis were rare and present also in cases destined to uneventful healing. Relative sclerosis and mottled appearance were present in uncomplicated cases as well as in necrosis and non-union cases.

Scintimetric evaluation of the healing process after femoral neck fractures was useful. In intact hips there was a specific distribution of activity; the highest activity was found in the medial and proximal part of the femoral head. In intact hips in the wedge-shaped area over the fovea the ^{85}Sr activity was twice that of the trochanteric area.

The results of ^{85}Sr -scintimetry two weeks after fracture were inconclusive and could not be used to predict the healing course of the fracture.

Four months after fracture the ^{85}Sr activity in the femoral head, the femoral neck and the trochanteric area was correlated to variations in the healing process; fractures destined for non-union had low uptake, notably in the trochanteric area. Fractures destined for necrosis had an increased uptake. The primary radiographic classification of the fractures with relation to displacement had importance for the scintimetric evaluation.

The living situation of patients with development of necrosis proved important for the decision whether or not a secondary arthroplasty was needed. Those who had partners seemed to avoid a secondary procedure. In these cases the indication for hip replacement should be carefully considered before they and their partners get used to concealed infirmity with risks for later social problems.

VI ACKNOWLEDGEMENTS

I am extremely grateful to the patients of this investigation and the personel of the Department of Orthopaedic Surgery and Diagnostic Radiology in Lund.

I wish to express my gratitude to Monica Gustavsson, Claes Westrup and Margaretha Persson for help with the technical data and equipment; Caroline Wallin for revising the manuscript and Jeanette Stenelo for typing the manuscript, Mona Olsson, Gerda Seidel, Kristina Persson och Birgitta Särgava for technical assistance.

This work was financially sponsored by Nordvästra Skånes Läkareförening, Greta and Johan Kocks Stiftelser, Stiftelsen för Bistånd åt Vanföra i Skåne, Alfred Österlunds Stiftelse and the Swedish Medical Research Council (Project 17X-02031).

VII REFERENCES

- Abdon, N.J., Nilsson, B.E.: Episodic cardiac arrhythmia and femoral neck fracture. *Acta Med Scand* 208: 73-76, 1980.
- Alffram, P.A.: An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population. *Acta Orthop Scand* 65, 1964.
- D'Ambrosia, R.D., Shoji, H., Riggins, R.S., Stadalnik, R.C., De Nardo, G.L.: Scintigraphy in the diagnosis of osteonecrosis. *Clin Orthop and Related Research* 130: 139-143.
- Asnis, S.E., Shoji, H., Bohne, W.H.: Scintimetric evaluation of complications after femoral neck fractures. *Clin Orthop and Related Research* 121: 149, 1976.
- Bauer, G.C.H., Ray, R.D.: Kinetics of strontium metabolism in man. *J Bone Jt Surg* 40-A: 171-186, 1958.
- Bauer, G.C.H., Wendeborg, B.: External counting of Ca^{17} and Sr^{85} in studies of localised skeletal lesions in man. *J Bone Jt Surg* 41-B: 558, 1959.
- Bauer, G., Weber, D.A., Ceder, L., Darte, L., Egund, N., Hansson, L.I., Strömqvist, B.: Dynamics of technetium -99m methylene-diphosphonate imaging of the femoral head after hip fracture. *Clin Orthop and Related Research* 152: 85-92, 1980.
- Bauer, G., Weber, D.A., Ceder, L., Darte, L., Egund, N., Hansson, L.I., Strömqvist, B.: Dynamics of post-traumatic necrosis of the femoral head studied with 99m-Tc MDP imaging techniques. Presented as Paper at the Twenty-Eight Annual Meeting of the Orthopaedic Research Society, New Orleans, Louisiana, January 21, 1982.
- Brümmer, R., Hansson, L.I., Mortensson, W., Sjöstrand, L.O.: ^{85}Sr -scintimetry in femoral neck fracture. *Arch Orthop Trauma Surg* 101: 47-51, 1982.
- Brümmer, R., Hansson, L.I., Mortensson, W.: A radiographic five-year follow-up of femoral neck fractures. *Acta Orthop Scand* (Accepted for publication).
- Cameron, R.B.: Strontium -85 scintimetry in nontraumatic necrosis of the femoral head. *Clin Orthop and Related Research* 65: 243-261, 1969.

- Catto, M.: Pathology of aseptic bone necrosis. Aseptic necrosis of bone. Excerpta Medica. Amsterdam 1976, ed by J.K. Davidson.
- Crock, H.V.: An atlas of the arterial supply of the head and neck of the femur in man. Clin Orthop and Related Research 152, 1980.
- Ceder, L., Ekelund, L., Inerot, S., Lindberg, L., Odberg, E., Sjölin, C.: Rehabilitation after hip fracture in the elderly. Acta Orthop Scand 50: 681-688, 1979.
- Ceder, L., Lindberg, L., Odberg, E.: Differentiated care of hip fracture in the elderly. Acta Orthop Scand 51: 157-162, 1980.
- Garden, R.S.: Low angle fixation in fractures of the femoral neck. J Bone Jt Surg 43-B: 647, 1961.
- Graham, J., Wood, S.K.: Aseptic necrosis of bone following trauma. Excerpta Medica, Amsterdam: 101-142, 1976.
- Hinchey, J.J., Day, P.L.: Primary prosthetic replacement in fresh femoral neck fractures. J Bone Jt Surg 46-A: 223-240, 1964.
- Hulth, A.: Prediction of the viability of the femoral head in femoral neck fractures. Acta Chir Scand 129: 72-80.
- Hunter, G.A.: Should we abandon primary prosthetic replacement for fresh displaced fractures of the neck of the femur? Clin Orthop and Related Research 152: 158-161, 1980.
- Jensen, J.S., Tøndevold, E.: Mortality after hip fractures. Acta Orthop Scand 50: 161-167, 1979.
- Riggins, R.S., De Nardo, G.L., D'Ambrosia, R., Goldman, M.: Assessment of circulation in the femoral head by ¹⁸F scintigraphy. Journal of Nuclear Medicine vol 15: 3, 183-186, 1973.
- Rydell, N.: Osteosynthesis of medial collum fractures with the "spring-loaded nail". Acta Orthop Scand 35: 149, 1964.
- Sevitt, S., Thompson, R.J.: The distribution and anastomoses of arteries supplying the head and neck of the femur. J Bone Jt Surg 47-B: 560-573, 1965.
- Sjöstrand, L.O.: Radionuclide scintimetry in total hip arthroplasty. Thesis Lund 1974.
- Sonne-Holm, S., Walter, S., Jensen, S.: Moore hemi-arthroplasty with and without bone cement in femoral neck fractures. Acta Orthop Scand 53: 953-956, 1982.

- Søreide, O., Mølster, A., Raugstad, T.: Replacement with the Christiansen endoprosthesis in acute femoral neck fractures. *Acta Orthop Scand* 51: 137-144, 1980.
- Subramanian, G., Mc Afee, J.G., O Mära, R.E., Rosenstreich, M., Mether, A. ^{99m}Tc polyphosphate PP 46: a new radiopharmaceutical for skeletal imaging. *J Nucl Med* 12: 399, 1971.
- Strömqvist, B.: Femoral head vitality after intracapsular hip fracture. 416 cases studied by intravital tetracycline labeling and Tc-MDP radio-nuclide scintimetry. Thesis Lund 1983.
- Trueta, J., Harrison, M.H.M.: The normal vascular anatomy of the femoral head in adult man. *J Bone Jt Surg* 35-B: 442-461, 1953.

NATURAL COURSE IN NAILED FRACTURES OF THE FEMORAL NECK
A FIVE-YEAR PROSPECTIVE INVESTIGATION

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SUMMARY

For five years following nailing of their cervical hip fractures 40 patients were examined repeatedly with ^{85}Sr scintimetry; radiography and clinical examinations. The mean age of the patients was 73 (38-93) years; 13 fractures healed without complications, 22 developed necrosis of the femoral head, and five non-union. Increasing weight-bearing pain was an early sign of necrosis or non-union, and it was the main indication for secondary arthroplasty. However, pain on weight-bearing was not always incapacitating, and five patients with necrosis had no complaints at all. The living situation of patients with development of necrosis proved important for the decision whether or not a secondary arthroplasty was needed; those who had partners seemed to avoid a secondary procedure. It is concluded that primary arthroplasty in fracture of the femoral neck should be avoided.

INTRODUCTION

The risk for necrosis of the femoral head following intracapsular fracture of the hip is generally regarded as 50 per cent or higher (Calandruccio and Anderson 1980). Therefore primary arthroplasty is often done in displaced fractures in elderly patients (Hunter 1980). However, the diagnosis of complications associated with avascularity of the femoral head can be done in the preradiographic stage with the aid of radionuclide scintimetry (Asnis et al 1976, Bauer et al 1980, Strömqvist 1983). An alternative strategy would therefore be to nail all or most fractures of the femoral neck, and then do a secondary arthroplasty in patients who have clinical symptoms of impending failure. The advantage of this strategy as compared to routine primary arthroplasty is that one avoids larger operations in those who will heal without complaints and in those who are destined to die from generalized disease before the necrosis has caused functional disability. This is a report on clinical and social observations followed prospectively for five years; results of ^{85}Sr -scintimetry and radiographic examinations in these patients have been published by Brummer et al (1982 and 1983).

Key words: Femoral neck fracture; Hip arthroplasty; Osteonecrosis; Non-union; Scintimetry

MATERIAL AND METHODS

The material of this prospective investigation comprised 40 patients with intracapsular subcapital or transcervical femoral fractures admitted to the Department of Orthopaedic Surgery, University Hospital in Lund during the period May 1975 - May 1976. Patients unable to cooperate or who did not have a radiographically normal contralateral hip were not selected for the investigation.

The mean age of the patients was 73 (38-93) years; all but six patients were older than 60 years. The patients were followed-up at four and six months and at one and two years, and they were interviewed at five years. Eight of the 40 patients died within five years.

The fractures were operated as soon as the patient's general condition and the resources of the surgical unit permitted, i.e. usually within 24-48 hours. Before the operation unstable fractures were treated with traction through the tibial tuberosity. The operation was performed under image intensifier control, and the Rydell (1964) four-flanged nail was used. The patients were encouraged to walk full weight-bearing the day after the operation (Ceder 1980).

Clinical data

The patients were followed-up clinically at four and six months, at one and two years, and they were interviewed five years after the fracture.

The clinical criteria were: pain at rest, pain on weight-bearing and walking capacity. The walking capacity was characterized as incapacity (walking less than ten metres), poor (walking with two quatraps or sticks), fair (walking with one stick and/or with a limp), or good (unrestricted walking ability). The mobility of the hip was recorded. The results were evaluated in relation to age, clinical status, and living situation.

Radiographic data

On admission the fractures were classified radiographically according to Garden's (1961) system modified according to Graham and Wood (1976). A

distinction was made between fractures with minor displacement (Garden I and II, 9 cases) and those with major displacement (Garden III and IV, 31 cases). On the basis of repeated examinations the fractures were classified as healing without complications (13 cases), femoral head necrosis (22 cases) or non-union (5 cases).

Scintimetric data

The scintimetry method used in this investigation was described by Bauer and Wendeberg (1959) and Sjöstrand (1974). Sr ⁸⁵ Scintimetry was performed two weeks and four months after the fracture (Brümmer et al 1982).

RESULTS

Eight of the 40 patients died during the five-year period, one from gastric cancer 1½ years after the fracture and the others from age-related vascular disease. In fractures with minor displacement six of nine healed without complications but in those with major displacement only seven of 31 escaped non-union or necrosis (Table 1).

Table 1. Classification of the fractures, the fate and age distribution

Fracture type	Uncompl healing	Necrosis	Non- union	Total	Mean age	(Range)
Minor displacement	6	3	0	9	73	(52-87)
Major displacement	7	19	5	31	73	(38-93)
Total	13	22	5	40	73	(38-93)

The over-all hospitalization time was 21 days; after exclusion of five patients who stayed for 37-88 days waiting for nursing home admission, the mean hospitalization time was 15 days.

Clinical examination

Six months after the fracture half of the hips destined for non-union or necrosis caused pain on weight-bearing but such pain was present also in one third of patients with uncomplicated healing (Table 2).

Table 2. Clinical investigation in femoral neck fractures with uncomplicated healing, and with necrosis and non-union

Frequency of	4 months		6 months		1 year		2 years	
	uncomp heal- ing n= 12	necr non- union n= 27	uncomp heal- ing n= 12	necr non- union n= 25	uncomp heal- ing n= 12	necr non- union n= 22	uncomp heal- ing n= 8	necr non- union n= 20
Pain at rest	0	5	2	5	1	5	3	7
Pain on weight-bearing	1	13	4	13	1	10	1	14
Poor walking capacity	3	8	3	8	2	3	0	3
Internal rotation 15° or less	2	11	3	10	5	16	5	15
Flexion 90° or less	3	9	1	7	2	8	5	15

Two years after the fracture the majority of patients with necrosis had pain on weight-bearing whereas the majority of those with uncomplicated healing now were pain-free. The range of motion, however, was significantly decreased in both complicated and uncomplicated cases at the two-year examination. The walking capacity, finally, was clearly best in the uncomplicated cases, and in the necrosis cases seemed influenced more by the age of the patient than of the fate of the femoral head.

Living situation

Five years after the fracture the living situation had changed in 15 of 40 patients (Table 3). Four patients (mean age 84 years) had moved from their own home to a home for the aged, three patients (mean age 84 years) to a nursing home, and eight patients had died. These changes in the liv-

ing situation were clearly related to age rather than to the local hip condition.

Table 3. Social outcome five years following femoral neck fracture

At fracture	n	Five years after fracture			
		Home	Home for aged	Nursing home	Dead
Home	31	22	4	3	2
Home for aged	3		1		2
Nursing home	6			2	4
	40	22	5	5	8

In nine of the patients, i.e. in nine of 27 cases of necrosis or non-union a salvage arthroplasty was performed. All of these lived in their home at the time of fracture, and all but one were living at home five years later. Six of those who had hip replacement were living alone in 1975 and in 1980. Three were living with someone in 1975, but one lost her partner a year after the fracture.

DISCUSSION

The prognosis after fracture of the hip is not good. In an unselected material the majority of the patients are octogenarians, many suffer from severe neurologic or cardiovascular disease (Ceder et al 1980, Abdon and Nilsson 1980), and 20-25 per cent are dead within a year (Alffram 1964, Ceder et al 1979). In the survivors rehabilitation is threatened by complications associated with disturbed fracture healing; in displaced intra-capsular fractures more than 50 per cent are destined for early problems due to non-healing or late segmental collapse of the femoral head. With this general background it is logical that improved methods for hip arthroplasty have led an increasing number of orthopaedic surgeons to recommend this procedure as primary treatment in fresh fractures of the femoral neck (Hunter 1980, Hinchey and Day 1964, Sonne-Holm et al 1982).

However, compared to nailing of the fracture a hip arthroplasty is costly and strenuous to the patient, and it has no advantage for patients destined to early death or to those who would have healed their fractures uneventfully following primary nailing. As recent literature does not contain any long-term studies of the prognosis following primary nailing the material presented here will be discussed in terms of the choice of treatment of fresh fractures of the femoral neck.

Protagonists of primary arthroplasty usually recommend this procedure for patients above age 60 with displaced fractures. With these criteria primary arthroplasty would have been performed in twenty-six cases of our displaced fractures; five displaced fractures in patients under 60 and nine undisplaced fractures would have had primary nailing. How many of these would have been unnecessary because of early death or uneventful healing? Let us first consider two criteria for evaluation of the therapy, immediate mobilization and the five year status.

If the choice of procedure were based on the capability of the patients to bear full weight on the hip the day after the operation no primary arthroplasty would have been indicated; in this material all the patients had a stable fracture after the operation and were able to walk immediately after the operation.

In terms of the five year prognosis a primary arthroplasty would have been retrospectively unrewarding for eight patients who died and seven who had displaced fractures which healed uneventfully. Furthermore the indications for a primary arthroplasty would have been rather vague in the majority of the osteonecrosis cases; 16 of 22 osteonecrosis cases had not been subjected to arthroplasty five years after the fracture. In the five non-unions on the other hand, an arthroplasty was performed in three within one year of the fracture, one died early, and one who is living at home has preferred not to have a secondary procedure. Even if we estimate that one half of the osteonecrosis cases which have not yet had a secondary procedure would have been better off with a primary procedure, as many as 22 of 31 displaced fractures would have had an unrewarding primary arthroplasty. Among the undisplaced fractures, however, three developed osteonecrosis;

with the criteria discussed here two of those, also had an unrewarding primary nailing of the fracture.

At this stage of the discussion it would seem that generally accepted rules for the choice of primary arthroplasty in fresh intracapsular fracture of the femoral neck are highly imprecise; two thirds of the patients recommended this procedure derive little or no benefit from this choice.

The lack of precision in deciding the prognosis after a fracture of the femoral neck is of course well known, and this problem has been addressed by a large number of investigators over the last thirty years. Most of the methods used for prediction of the vascularity of the femoral head have been invasive, time consuming and/or imprecise (Hulth 1965). The only practical avenue that still remains seems to be the use of bone seeking γ -emitting radionuclides, notably ^{85}Sr (Bauer and Ray 1958, Cameron 1969), ^{18}F (Riggins et al 1973) and especially technetium (Subramanian et al 1971) labelled phosphonates. This investigation shows that ^{85}Sr , for reasons unknown, does not permit a diagnosis of non-vascularity in fresh fractures of the femoral head, and like ^{18}F the method is impractical as compared to technetium labelled phosphonates. D'Ambrosia et al (1978) and Bauer and Hansson and their co-workers (1980, 1982) have now shown that this technique permits a rapid and precise diagnosis of femoral head avascularity, suitable for a preoperative choice between nailing and arthroplasty in fractures of the femoral neck.

However, this investigation does not support the choice of a primary arthroplasty even if a precise preoperative diagnosis of femoral head avascularity can be done. Following primary nailing of the fracture only a minority had such severe complications, notably non-union, that an arthroplasty was required to maintain function. The majority of the patients with complications associated with avascularity of the femoral head, notably segmental collapse, had rather mild symptoms; the decision whether or not to have an arthroplasty seemed to be based more on social conditions than on the function of the hip. Finally, even though the nature of this long-term investigation discriminated particularly fragile patients from inclusion, several patients were dead before they would have had any benefit from a primary arthroplasty. In this material the five non-unions were

all diagnosed within one year, one of those died and the three secondary arthroplasties were all performed within nine months of the fracture. By contrast half of the necrosis cases had a radiographic diagnosis after more than one year (Table 4), and four of the six secondary arthroplasties were performed two years or more after the fracture. When the incidence and time table of the development of hip problems, associated with the fracture, are compared with the 20-30 per cent (Hunter 1980) one-year mortality in unselected materials of hip fracture, the case for primary arthroplasty in this condition seems weak indeed.

Table 4. Time of radiographic diagnosis: necrosis (N) and pseudarthrosis/non-union (P) after 40 femoral neck fractures

	Within 1 year	1-2 years	2-3 years	3-4 years	4-5 years
Case no	4 N	10 N	40 N	3 N	6 N
	7 N	12 N		33 N	
	9 N	15 N			
	11 N	20 N			
	18 N	34 N			
	24 N	37 N			
	29 N	38 N			
	30 P	44 N			
	42 P	57 N			
	45 N*				
	46 N*				
	52 P*				
	54 P				
	59 P				
Number	14	9	1	2	1
Percentage of the material	35 %	58 %	60 %	65 %	68 %

* cases with negative radiographic findings

The strategy for treatment of intracapsular fracture of the femoral neck applied here does not end with the choice of nailing as the primary procedure. Rather, the technical handling of the hip problem is dovetailed to programs for mobilisation and rehabilitation developed over a 10-year period of trial and error (Ceder 1981). After five years two thirds of the patients in this material who suffered their fracture while living at home were still at home, and the number of patients under institutional care was unchanged (Table 3). Valid comparisons of strategies and tactics for handling of the extremely complicated problem of the fractured hip in the aged should include information on the long-term social outcome.

REFERENCES

- Abdon, N.J., Nilsson, B.E.: Episodic cardiac arrhythmia and femoral neck fracture. *Acta Med Scand* 208: 73-76, 1980.
- Alffram, P.A.: An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population. *Acta Orthop Scand*, suppl 65, 1964.
- D'Ambrosia, R.D., Shoji, H., Riggins, R.S., Stadalnik, R.C., De Nardo, G.L.: Scintigraphy in the diagnosis of osteonecrosis. *Clin Orthop and Related Research* 130: 139-143, 1978.
- Asnis, S.E., Shoji, H., Bohne, W.H.: Scintimetric evaluation of complications after femoral neck fractures. *Clin Orthop and Related Research* 121: 149, 1976.
- Bauer, G.C.H., Ray, R.D.: Kinetics of strontium metabolism in man. *J Bone and Jt Surg* 40-A: 171-186, 1958.
- Bauer, G.C.H., Wendeberg, B.: External counting of Ca^{17} and Sr^{85} in studies of localised skeletal lesions in man. *J Bone and Jt Surg* 41-B: 558, 1959.
- Bauer, G., Weber, D.A., Ceder, L., Darte, L., Egund, N., Hansson, L.I., Strömqvist, B.: Dynamics of technetium -99m methylene-diphosphonate imaging of the femoral head after hip fracture. *Clin Orthop and Related Research* 152: 85-92, 1980.
- Bauer, G., Weber, D.A., Ceder, L., Darte, L., Egund, N., Hansson, L.I., Strömqvist, B.: Dynamics of post-traumatic necrosis of the femoral head studied with 99m - Tc MDP imaging techniques. Presented as Paper at the Twenty-Eight Annual Meeting of the Orthopaedic Research Society, New Orleans, Louisiana, January 21, 1982.

- Brümmer, R., Hansson, L.I., Mortensson, W., Sjöstrand, L.O.: ^{85}Sr -Scintimetry in femoral neck fracture. Arch Orthop Traum Surg 101: 47-51, 1982
- Brümmer, R., Hansson, L.I., Mortensson, W.: A radiographic five-year follow up of femoral neck fractures. Accepted for publication in Acta Orthop Scand 1983.
- Cameron, R.B.: Strontium -85 Scintimetry in nontraumatic necrosis of the femoral head. Clin Orthop and Related Research 65: 243-261, 1969.
- Ceder, L., Ekelund, L., Inerot, S., Lindberg, L., Odberg, E., Sjölin, C.: Rehabilitation after hip fracture in the elderly. Acta Orthop Scand 50: 681-688, 1979.
- Ceder, L., Lindberg, L., Odberg, E.: Differentiated care of hip fracture in the elderly. Acta Orthop Scand 51: 157-162, 1980.
- Garden, R.S.: Low angle fixation in fractures of the femoral neck. J Bone and Jt Surg 43-B: 647, 1961.
- Graham, J., Wood, S.K.: Aseptic necrosis of bone following trauma. Excerpta Medica, Amsterdam, pp 101-142, 1976.
- Hinchey, J.J., Day, P.L.: Primary prosthetic replacement in fresh femoral neck fractures. J Bone and Jt Surg 46-A: 223-240, 1964.
- Hulth, A.: Prediction of the viability of the femoral head in femoral neck fractures. Acta Chir Scand 129: 72-80, 1965.
- Hunter, G.A.: Should we abandon primary prosthetic replacement for fresh displaced fractures of the neck of the femur? Clin Orthop and Related Research 152: 158-161, 1980.
- Riggins, R.S., De Nardo, G.L., D'Ambrosia, R., Goldman, M.: Assessment of circulation in the femoral head by ^{18}F scintigraphy. J Nucl Med 15: 183-186, 1973.
- Rydell, N.: Osteosynthesis of medial collum fractures with the "spring-loaded nail". Acta Orthop Scand 35: 149, 1964.
- Sjöstrand, L.O.: Radionuclide scintimetry in total hip arthroplasty. Thesis Lund, 1974.
- Sonne-Holm, S., Walter, S., Jensen, S.: Moore hemi-arthroplasty with and without bone cement in femoral neck fractures. Acta Orthop Scand 53: 953-956, 1982.
- Subramanian, G., McAfee, J.G., OMara, R.E., Rosenstreich, M., Mether, A.: $^{99\text{m}}\text{Tc}$ polyphosphate PP 46: a new radiopharmaceutical for skeletal imaging. J Nucl Med 12: 399, 1971.

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416 cases studied by intravital tetracycline labeling and Tc-MDP radio-nuclide scintimetry. Thesis, Lund, 1983.

A RADIOGRAPHIC FIVE-YEAR FOLLOW-UP OF FEMORAL NECK FRACTURES

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ABSTRACT

Forty femoral neck fractures were followed for five years in a prospective clinical, roentgenographic and scintimetric investigation. Thirteen cases had uncomplicated healing, 22 necrosis and 5 non-union.

The diagnostic value of radiographical changes was analysed with reference to development of necrosis of the femoral head or non-union. Sclerosis of the femoral head, and compression and displacement of the fracture were compatible with eventual healing and clinical recovery.

Subchondral fracture and collapse of the load-bearing surface, diagnostic for necrosis, were observed in only 7 of 22 cases at one year and as late as 3-5 years in 3 cases. By contrast 4 out of 5 non-union cases were established radiographically within one year.

Patients needing an arthroplasty after fracture of the femoral neck should be identified on clinical grounds after early radionuclide scintimetry. Waiting for radiographic documentation of necrosis in cases with pain will increase the risk for physical and social impairment associated with poor function of the hip.

INTRODUCTION

Recent literature does not contain any long-term investigation of the diagnostic value of radiographic changes in the femoral head and neck after intracapsular hip fracture. Radiographic changes up to five years in cases destined to uncomplicated healing, necrosis or non-union/pseudarthrosis was compared with findings of ^{85}Sr -scintimetry at four months in order to define the indications for radiographs and to examine more closely the value of radiographic examinations in the management of hip fracture.

Key words: Femoral Neck Fracture; Osteonecrosis; Non-Union; Radiography; Scintimetry

MATERIAL AND METHODS

The material of this prospective investigation comprised 40 patients with intracapsular subcapital or transcervical femoral fractures admitted to the Department of Orthopaedic Surgery, University Hospital in Lund during the period May 1975 - May 1976. Patients unable to cooperate or who did not have a radiographically normal contralateral hip were not selected for the investigation.

The mean age of the patients was 73 (38-93) years; all but six patients were older than 60 years (Table 1). The patients were followed-up at four and six months and at one and two years, and they were interviewed at five years. Eight of the 40 patients died within five years.

The fractures were operated as soon as the patient's general condition and the resources of the surgical unit permitted, i.e. usually within 24-48 hours. Before the operation unstable fractures were treated with traction through the tibial tuberosity. The operation was performed under image intensifier control, and the Rydell (1964) four-flanged nail was used. The patients were encouraged to walk full weight-bearing the day after the operation (Ceder 1980).

The patients were followed-up clinically at four and six months, at one and two years, and they were interviewed five years after the fracture.

Radiographic data (Table 1)

On admission the hips were radiographed in antero-posterior and lateral projections and the fractures were classified according to Garden's (1962) system modified according to Graham and Wood (1976). A distinction was made between fractures with minor displacement (Garden I and II, 9 cases) and those with major displacement (Garden III and IV, 31 cases). The fractures were classified as healing without complications (13 cases) when there was no appearance of collapse of the femoral head and the fracture was not visible, as non-union (5 cases) when the fracture was visible with sclerotic bone on one or both sides, or necrosis (22 cases). Necrosis was diagnosed when compression of the loadbearing surface and subchondral

fracture was observed. The diagnosis was confirmed histologically in those patients who had a secondary arthroplasty. In certain cases the patients were followed radiographically for three, four and even five years if necrosis had not been visible in earlier examinations.

Table 1. Classification and end results of femoral neck fractures

Fracture type	Uncompl healing	Necrosis	Non- union	Total	Mean age	(Range)
Minor displacement	6	3	0	9	73	(52-87)
Major displacement	7	19	5	31	73	(38-93)
Total	13	22	5	40	73	(38-93)

RESULTS

The fate of the fractures was correlated to the preoperative displacement and the postoperative position (Table 2).

Table 2. Postoperative position and end results of femoral neck fractures

Fracture displacement		Uncompl healing	Necrosis	Non- union	Total
Preoperative	Postoperative				
Minor	Satisfactory	4	3	-	7
	Varus	-	-	-	-
	Valgus	2	-	-	2
		6	3	-	9
Major	Satisfactory	4	12	3	19
	Varus	1	1	-	2
	Valgus	2	6	2	10
		7	19	5	31

Uncomplicated healing (Table 3)

Compression in the fracture area was present in 3 of 13 uncomplicated healing cases at four months. In two cases of those with major displacement, compression had increased at six months but further changes did not occur. Displacement without further changes was noted in one case at four months.

Sclerosis in the femoral head was present at four months in 3/13 cases and in one more case at six months. Increased changes at six months and one year occurred in 3/12 and 4/12 cases. In no case did sclerosis disappear within the time of observation.

Table 3. Radiographic observations in femoral neck fractures with uncomplicated healing

a = new changes

c = unchanged to preceding investigation

b = increased changes

d = no changes

Changes in	4 months				6 months				1 year				2 years			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
Femoral neck																
compression	3	-	-	10	-	2	1	9	-	-	3	9	-	-	2	7
displacement	1	-	-	12	-	-	1	11	-	-	1	11	-	-	1	8
Femoral head																
sclerosis	3	-	-	10	1	3	-	8	-	4	-	8	-	1	1	7
Dead											1				3	
Refused investigation							1								1	

Necrosis (Table 4)

Compared with postoperative radiographs no changes at all were observed in 7/22 necrosis cases at four months, in 6/21 at six months, in 5/20 at one year and in only one of 18 cases examined two years after fracture.

In contrast to uncomplicated healing cases compression in the femoral neck was more frequent in necrosis cases. About two thirds of the necrosis cases showed compression at four months; this compression had increased at six months in one third of these cases.

Displacement of the femoral head was found in three cases at four months; in one of them the displacement increased, but none of these cases had hip replacement. One case had displacement two years after the fracture and had hip replacement at three years.

The fracture gap had disappeared by two years in all the necrosis cases.

Sclerosis was seen later than in uncomplicated healing cases, and it increased during the follow-up.

Subchondral fracture was not observed before the one-year examination; at two years a subchondral fracture was present in 7 of 18 cases of necrosis.

Segmental collapse was diagnosed in one case at four months. This was an 85-year old woman with Parkinson's disease and dementia who had been operated on twice because of inadequate primary reduction and fixation. After the second operation the nail penetrated the femoral head. Except for this case segmental collapse was present at six months in one of three cases with minor displacement and in none of the 19 cases with major displacement. One year after fracture segmental collapse was found in four cases, and after two years in another four cases, all with initial major displacement.

Table 4. Radiographic changes in femoral neck fractures with necrosis

a = new changes

c = unchanged to preceding investigation

b = increased changes

d = no changes

Changes in	4 months				6 months				1 year				2 years			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
Femoral neck																
compression	13	-	-	9	-	7	6	8	1	3	8	8	1	3	8	6
displacement	3	-	-	19	-	1	2	18	-	-	3	17	1	-	3	14
fracture gap	2	-	-	20	1	-	2	18	1	-	3	16	-	-	-	18
Femoral head																
sclerosis	4	-	-	18	7	4	-	10	4	8	1	7	4	11	1	2
subchondral fracture	-	-	-	22	-	-	-	21	2	-	-	18	5	1	1	11
segmental collapse	1	-	-	21	1	-	1	19	4	1	1	14	4	3	3	8
Refused investigation			-				1				-				1	
Hip arthroplasty			-				-				2				3	
Total			22				22				22				22	

Non-union (Table 5)

Non-union developed only in fractures with major displacement. Radiographic changes were mostly observed in the femoral neck, such as compression in all five cases, displacement in three of five cases and a fracture gap in three of five cases. In the femoral head sclerosis was present in both non-reoperated cases at the one and two year examinations.

Table 5. Radiographic changes in femoral neck fractures with major displacement and non-union

a = new changes

c = unchanged to preceding investigation

b = increased changes

d = no changes

Changes in	4 months				6 months				1 year				2 years			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
Femoral neck																
compression	4	-	-	1	1	3	-	-	-	1	1	-	-	2	-	-
displacement	2	-	-	3	-	1	-	3	-	-	-	2	1	-	-	1
fracture gap	1	-	-	4	-	1	-	3	-	-	-	2	2	-	-	-
Femoral head																
sclerosis	2	-	-	3	1	2	-	1	-	1	1	-	-	2	-	-
Hip arthroplasty			-				1				3				3	
Total			5				5				5				5	

DISCUSSION

In the management of femoral neck fractures radiographic examinations are indispensable for the diagnosis, and for guidance and control of the nailing procedure. In the further postoperative course their value is rather limited. This investigation has demonstrated that early compression and even displacement of the fracture and sclerosis of the femoral head may occur without future non-union or late segmental collapse (Figs 1 and 2).

RADIOGRAPHIC CHANGES IN THE FRACTURE AREA				
CASE	4	6	12	24 MONTHS
1	-	-	-	-
5	-	-	-	R
13	△	△	△	△
17	△	△	△	△
21	○	○	○	○
23	-	-	-	-
27	△	△	△	D
28	-	-	D	D
39	-	-	-	-
47	-	-	-	-
49	-	-	-	D
51	-	-	-	-
58	-	-	-	-
3	-	-	-	-
4	△	△	△	△
6	-	-	△	△
7	⊗	⊗	⊗	⊗
9	-	R	-	-
10	△	△	△	△
11	△	△	△	△
12	○	○	○	⊗
15	□	□	□	-
18	-	-	-	-
20	△	△	△	△
24	⊗	⊗	⊗	⊗
29	△	△	△	⊗
33	△	△	△	R
34	△	△	△	△
37	△	△	△	△
38	△	△	△	△
40	-	-	-	-
44	-	-	-	-
45	△	△	H	H
46	△	△	H	H
57	-	-	-	H
30	△	△	△	△
42	△	△	△	⊗
52	△	△	H	H
54	⊗	⊗	H	H
59	⊗	H	H	H

△ COMPRESSION
 ○ DISPLACEMENT
 □ FRACTURE GAP
 R REFUSED INVESTIGATION
 H HIP ARTHROPLASTY
 D DEAD
 - NO CHANGES

Fig 1. Radiographic changes in femoral neck fractures (40).

RADIOGRAPHIC CHANGES IN THE FEMORAL HEAD				
CASE	4	6	12	24 MONTHS
1	-	-	-	-
5	△	△	△	R
13	-	-	-	-
17	-	-	-	-
21	-	-	-	-
23	-	-	-	-
27	-	-	-	D
28	-	-	D	D
39	△	△	△	△
47	-	-	-	-
49	△	△	△	D
51	-	△	△	△
58	-	-	-	-
3	-	-	-	-
4	△	△	△	△
6	-	-	-	△
7	□	□	□	△
9	-	R	△	△
10	-	-	△	△
11	-	□	△	△
12	-	△	△	△
15	-	-	-	⊗
18	-	-	⊗	⊗
20	-	-	-	⊗
24	△	△	△	⊗
29	△	△	⊗	⊗
33	-	-	-	R
34	-	△	△	△
37	-	△	△	⊗
38	-	△	△	⊗
40	-	-	-	△
44	△	△	△	△
45	-	△	H	H
46	-	△	H	H
57	-	△	△	H
30	△	△	△	△
42	-	△	△	△
52	-	-	H	H
54	△	△	H	H
59	-	H	H	H

△ SCLEROSIS
 ○ SUBCHONDRAL FRACTURE
 □ SEGMENTAL COLLAPSE
 H HIP ARTHROPLASTY
 R REFUSED INVESTIGATION
 D DEAD
 - NO CHANGES

Fig 2. Radiographic changes in femoral neck fractures (40).

Furthermore, even if sequential radiographic examinations were predictive of complications, their value is limited by the lack of technology for changing the natural course of the failing femoral neck fracture. The procedure in such cases, a hemi- or total arthroplasty, is undertaken not on the basis of radiographs but because of impaired function of the hip, i.e. on clinical grounds; in this material only one third of the patients with segmental collapse and/or subchondral fracture had an arthroplasty within five years of the fracture (Brümmer 1983).

Routine radiographic examinations of intracapsular hip fractures would thus seem dispensable after the immediate postoperative period.

However, definite radiographic evidence of femoral head collapse is often not available until two years or more after the fracture. In some of these cases an early secondary arthroplasty would prevent physical and social decay. Pain does not suffice as an indication for a secondary operation; in this material one third of those who healed their fractures without structural complications had pain on weight-bearing at six months (Brümmer 1983). The radiographic classification based on initial displacement is likewise imprecise in the prediction of complications; three of the nine Garden I and II fractures had structural complications.

Here radionuclide techniques should replace radiographic examinations in the decision process whether or not to consider a secondary procedure. In this material (Brümmer 1982) ^{85}Sr scintimetry at four months was predictive of non-union (low values) or late collapse (high values) (Figs 3 and 4). However, this method has little predictive value when applied to fresh fractures.

MINOR DISPLACEMENT

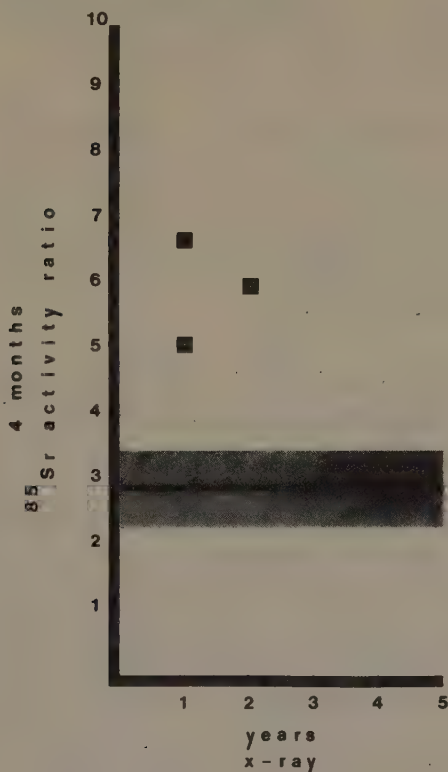


Fig 3.

MAJOR DISPLACEMENT

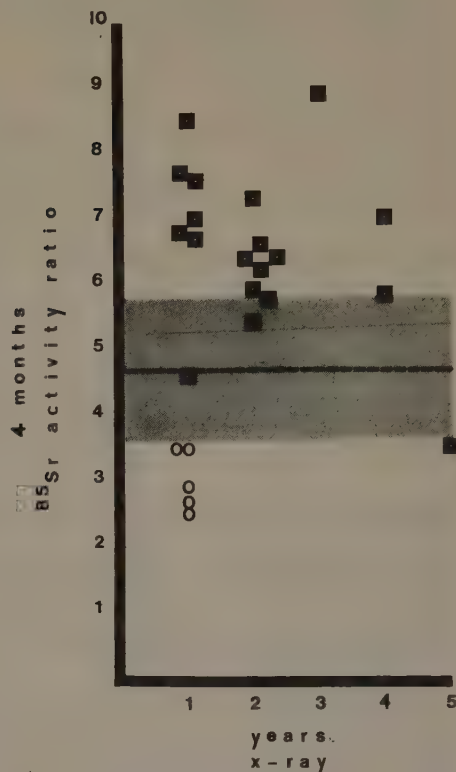


Fig 4.

Fig 3. ^{85}Sr activity ratio in the c_4 -sector (base of femoral head and subcapital area of the femoral neck) at four months. Cases with minor displacement and necrosis in relation to the time of radiographic diagnosis.

Grey zone = activity ratio in uncomplicated healing cases

■ = activity ratio in necrosis

Fig 4. ^{85}Sr activity ratio in the c_4 -sector (base of femoral head and subcapital area of the femoral neck) at four months. Cases with major displacement and necrosis respectively pseudarthrosis/non-union in relation to the time of radiographic diagnosis

Grey zone = activity ratio in uncomplicated healing cases

■ = activity ratio in necrosis

○ = activity ratio in pseudarthrosis/non-union

Strömqvist (1983) has now summarized the experience in this department from the use of ^{93}Tc labelled methylene diphosphonate for evaluation of the vitality of the femoral head in fresh intracapsular hip frac-

tures (D'Ambrosia et al 1978, Bauer et al 1980). It appears that this technique permits a near perfect distinction between femoral neck fractures destined to uncomplicated healing and those destined to non-union or collapse of the femoral head.

The place of radiographic examinations in fracture of the femoral neck should thus be limited to preoperative diagnosis and classification, per-operative guidance, and to early postoperative control after weight-bearing to check the mechanical solidity of the fracture. Routine radiographic examinations of the subsequent course are superfluous - and expensive - because they have little predictive value and hardly any effect on management of the fractures.

REFERENCES

- D'Ambrosia, R.D., Shoji, H., Riggins, R.S., Stadalnik, R.C., De Nardo, G.L.: Scintigraphy in the Diagnosis of Osteonecrosis. Clin Orthop and Related Research 130: 139, 1978.
- Bauer, G., Ceder, L., Darte, L., Egund, N., Hansson, L.I., Strömqvist, B., Weber, D.: Dynamics of Technetium -99m Methylenediphosphonate Imaging of the Femoral Head after Hip Fracture. Clin Orthop and Related Research 152: 85-92, 1980.
- Brümmer, R., Hansson, L.I., Mortensson, W., Sjöstrand, L.O.: ^{85}Sr -Scintimetry in Femoral Neck Fracture, Arch Orthop Traum Surg 101: 47-51, 1982.
- Brümmer, R.: Natural course in nailed fractures of the femoral neck. A five-year prospective investigation. (Will be published).
- Ceder, L., Lindberg, L., Odberg, E.: Differentiated Care of Hip Fracture in the Elderly. Acta Orthop Scand 51: 157-162, 1980.
- Garden, R.S.: Low Angle Fixation in Fractures of the Femoral Neck. J Bone and Jt Surg 43-B: 647, 1961.
- Graham, J., Wood, S.K.: Aseptic Necrosis of Bone Following Trauma. Excerpta Medica, Amsterdam, 101-142, 1976.
- Rydehl, N.: Osteosynthesis of Medial Collum Fractures with the "Spring-loaded Nail". Acta Orthop Scand 35: 149, 1964.
- Strömqvist, B.: Femoral Head Vitality after Intracapsular Hip Fracture. 416 cases studied by intravital tetracycline labeling and Tc-MDP radio-nuclide scintimetry. Thesis, Lund, 1983.

⁸⁵Sr-Scintimetry in Femoral Neck Fracture

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Summary. In 40 patients with fracture of the femoral neck ⁸⁵Sr scintimetry was performed at the time of nailing and 4 months postoperatively. The fractures were radiographed repeatedly for 5 years; thirteen fractures healed without complications, 22 developed necrosis of the femoral head, and 5 pseudarthrosis. The early isotope measurement did not distinguish between normal and necrosis cases even with detailed analysis. The 4 months activities were high in osteonecrosis and low pseudarthrosis. The latter observation is interpreted as evidence that non-union of a femoral neck fracture is due to severe permanent vascular damage.

Zusammenfassung. Bei 40 Patienten mit einer Schenkelhalsfraktur wurde im Zeitraum der Nagelung und 4 Monate postoperativ eine ⁸⁵Sr-Szintimetrie durchgeführt. Während 5 Jahren wurden außerdem wiederholt Röntgenaufnahmen angefertigt: Dreizehn Frakturen heilten ohne Komplikationen, 22 entwickelten eine Hüftkopfnekrose und 5 eine Pseudarthrose.

Die frühzeitige Isotopenuntersuchungen ließen, selbst bei detaillierten Analysen, keinen Unterschied erkennen zwischen den Fällen, die normal heilten, und denen, die eine Nekrose entwickelten. Bei den Untersuchungen nach 4 Monaten waren die Aktivitäten bei Osteonekrosen hoch und bei Pseudarthrosen niedrig. Diese Beobachtung wird als Hinweis dafür angesehen, daß eine Schenkelhalspseudarthrose auf eine schwere Dauerschädigung der Gefäße zurückzuführen ist.

Introduction

The cause of necrosis of the head of femur following cervical fracture was established as primary vascular damage more than 150 years ago by Cooper (1824) in a

brilliant series of clinical observations and animal experiments. However, vascular damage with death of bone cells does not suffice to explain the eventual threat to the structural integrity of the bone tissue: the fate of the necrotic head of femur is determined by the balance of formation and resorption of bone in the course of revitalization. Cameron (1969) and Asnis et al. (1976) demonstrated that the anabolic phase of these processes can be visualized with the aid of non-invasive ⁸⁵Sr scintimetry, and these techniques have been widely applied in the diagnosis of osteonecrosis in the radiographic silent early stage. The present investigation was initiated in the hope that such techniques could identify metabolically deficient heads of femur and correlate subsequent repair reactions with morphologic entities of the proximal femur. From its inception the investigation was planned to follow the clinical and the radiographic development of complications to femoral neck fracture for five years.

Material and Methods

The material of this prospective investigation comprised 40 patients with intracapsular subcapital or transcervical femoral fractures admitted to the Department of Orthopaedic Surgery, University Hospital in Lund during the period May 1975–May 1976. Patients unable to cooperate or who did not have a radiographically normal contralateral hip were not selected for the investigation.

The mean age of the patients was 73 years (range 38–93 years). The patients were followed-up at four and six months and at one and two years, and they were interviewed at five years. Eight of the 40 patients died within 5 years.

The fractures were operated as soon as the patients' general condition and the resources of the surgical unit permitted, i.e. usually within 24–48 h. Before the operation unstable fractures were treated with traction through the tibial tuberosity. The operation was performed under image intensifier control, and the Rydell (1964) four-flanged nail was used. The patients were encouraged to walk full weight-bearing the day after the operation.

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Table 1. Classification and fate of 40 fractures of the femoral neck

Fracture type	Uncomplicated healing	Necrosis	Pseudarthrosis	Sum	Secondary arthroplasty
Minor displacement (Garden I + II)	6	3	0	9	1
Major displacement (Garden III + IV)	7	19	5	31	8
Sum	13	22	5	40	9

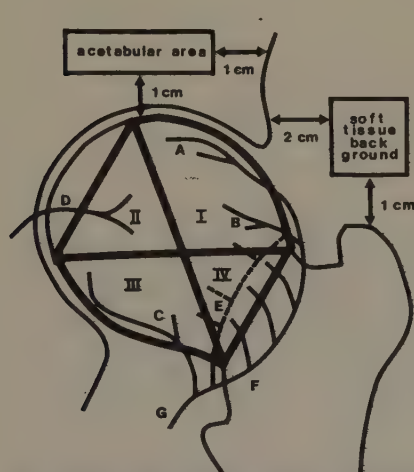


Fig. 1. Blood supply to the femoral head in the adult according to Trueta and Harrison (1953), Sevitt and Thompson (1965), Catto (1976), Graham and Wood (1976), Crock (1980). A, lateral epiphysial artery; B, superior metaphysial artery; C, inferior metaphysial artery; D, foveal (medial epiphysial) artery; E, medial femoral circumflex artery; F, lateral femoral circumflex artery; G, profunda femoris artery. The areas of interest for ^{85}Sr activity measurements have been superimposed on the outline of the radiograph

Radiographic Data

On admission the hips were radiographed in antero-posterior and lateral projections and the fractures were classified according to Garden's (1961) system modified according to Graham and Wood (1976). A distinction was made between fractures with *minor displacement* (Garden I and II, 9 cases) and those with *major displacement* (Garden III and IV, 31 cases). The fractures were classified as healing *without complications* (13 cases) when there were no changes in bone density and the fracture was not visible, as *pseudarthrosis* (5 cases) when the fracture was visible with sclerotic bone on one or both sides, or *necrosis* (22 cases); in certain cases the patients were followed radiographically for three, four and even five years if necrosis had not been visible in earlier examinations and there were clinical reasons to suspect complications. Necrosis was considered present when a patchy sclerosis and compression of the load-bearing surface and subchondral fracture was observed. The diagnosis was confirmed histologically in those patients who had a secondary arthroplasty.

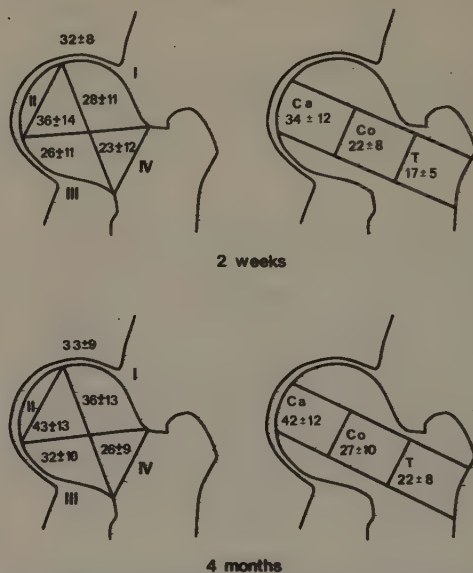


Fig. 2. Mean ^{85}Sr activity in different sectors of 29 intact hips 2 weeks and 4 months after fracture

Scintimetry Method

The scintimetry method and equipment used in this investigation have been described by Sjöstrand (1974). Each patient received an intravenous injection of 100 μCi carrierfree ^{85}Sr , before the operation in 10 patients and within 9 days after the operation in 30 patients. Scintimetry of both hips was performed after two weeks (Bauer and Wendeberg 1959). All 40 patients received a new injection of 100 μCi ^{85}Sr after four months and two weeks later scintimetry was performed.

Areas of Interest (Fig. 1). With the patient supine the neutral position of the hips was fixed with sand bags. An AP radiogram of the hips was obtained immediately before or after the scintimetry procedure. With the aid of the radiogram the scintimetry pattern of the femoral head was divided into four sectors, the upper (I), medial (II), lower (III) and lateral (IV). Within these sectors the mean counting rates were calculated. Borderline data were alternatively accepted and excluded. The mean value of the acetabular area was obtained from 8 cells in an area located 1 cm proximal to the femoral head and 1 cm medial to the lateral border of the pelvis. Finally a 24 mm wide area around the nail was identified and the activity values in the trochanter (T), neck (Co) and head (Ca) areas were recorded.

Table 2. ^{85}Sr activity ratios at 4 months in femoral neck fractures which healed without complications. Fractures with minor and major displacement were compared

Displacement		Areas of interest						
		I	II	III	IV	Ca	Co	T
Minor ($n = 6$)	$\bar{x}$	1.9	2.2	3.0	2.9	2.1	3.0	2.0
	s	0.5	0.8	1.0	0.6	0.9	0.7	0.5
Major ($n = 7$)	$\bar{x}$	2.9*	2.5 ⁽⁻⁾	4.0 ⁽⁻⁾	4.7**	2.6 ⁽⁻⁾	4.9*	4.0***
	s	1.0	1.1	2.0	1.1	0.9	1.4	0.8

Student's t -distribution: $-$ = insignificant $P > 0.05$; * = almost significant $0.05 > P > 0.01$; ** = significant $0.01 > P > 0.001$; *** = highly significant $P < 0.001$; $\bar{x}$ = arithmetic mean; s = standard deviation

Table 3. ^{85}Sr scintimetry at 4 months in necrosis cases. In each displacement group the activity data were compared with the normally healing fractures

Displacement		Areas of interest						
		I	II	III	IV	Ca	Co	T
Minor ($n = 3$)	$\bar{x}$	3.1**	3.7*	4.4 ⁽⁻⁾	5.9***	3.2 ⁽⁻⁾	5.5**	4.9**
	s	0.3	0.5	0.8	0.8	0.5	0.7	1.8
Major ($n = 19$)	$\bar{x}$	3.0 ⁽⁻⁾	2.6 ⁽⁻⁾	4.4 ⁽⁻⁾	6.5**	2.9 ⁽⁻⁾	6.6 ⁽⁻⁾	5.2 ⁽⁻⁾
	s	1.0	1.0	1.3	1.3	1.0	2.1	1.9

Table 4. ^{85}Sr activity ratios at 4 months in fractures with major displacement and development of pseudarthrosis. Comparison was made with normally healing fractures

Displacement		Areas of interest						
		I	II	III	IV	Ca	Co	T
Major ($n = 5$)	$\bar{x}$	1.9 ⁽⁻⁾	1.5 ⁽⁻⁾	2.0 ⁽⁻⁾	3.0**	1.9 ⁽⁻⁾	3.1*	2.8*
	s	0.5	0.3	0.5	0.5	0.4	0.4	0.6

Data Presentation. The mean counting rates within the areas of interest were corrected for background activity (Fig. 2) measured in an area 1 cm proximal to the greater trochanter and 2 cm lateral to the lateral border of the acetabulum. The room background activity was about 4 counts/10 s, and the soft tissue background was about 6 counts/10 s. In order to account for individual variations in the metabolism of strontium the ^{85}Sr activity values recorded over the fractured hips were expressed as ratios relative to the values recorded over identical areas of interest of the contralateral intact hip. Under the conditions specified by Bauer and Wendeberg (1959) these ratios were interpreted as relative rates of bone formation.

Blood Supply to the Femoral Head. With reference to Fig. 1 the blood supply to the femoral head is roughly identified with the four sectors as follows. The upper sector receives its main blood supply by the lateral epiphyseal arteries and the superior metaphyseal artery. The medial sector is nourished by the medial epiphyseal artery in the ligamentum teres. The lower sector is nourished by the inferior metaphyseal arteries. The blood supply of the lateral sector which includes the fracture area with part of the femoral neck is provided by invasion from the distal fragment (Santos 1930; Sevitt 1964) and by the superior and inferior metaphyseal arteries (Trueta and Harrison 1953; Calandruccio and Anderson 1980; Crock 1980).

Results

Intact Hips

The distribution of activity in the upper femur of the intact hips was markedly uneven as recorded at two weeks in 29 cases and at four months in all 40 cases (Fig. 2). The medial head sector had the highest activity and the trochanter area had the lowest (Fig. 2). Highly significant differences were found between the medial and lateral sectors of the femoral head, between the head and neck areas, and between the head and trochanter areas. In general the activity was somewhat higher in the femur at four months than at two weeks except in the acetabulum.

Fresh Fractures

As compared to the intact hips the scintimetry values of hips with fresh fractures were generally increased by some 50% except the acetabular area, which did not have increased activity. The activity values were not

influenced by the time the isotope injection was made in relation to the operation nor could they be used to predict the healing course of the fractures.

Fractures at Four Months

The activities of the fractured hips at 4 months were in general considerably increased with marked variations for areas, degree of displacement and the fate of the fracture (Tables 2–4).

Uncomplicated Healing (Table 2). In contrast to intact hips, where the ^{85}Sr activity in the medial femoral head sector was about twice the trochanter's, the activity in the trochanteric area was increased to the same or even higher values in fractured hips.

In sector IV and in the trochanteric area the activity was significantly higher in fractures with major displacement than in fractures with minor displacement. In the other areas of the upper femur the ratio was somewhat higher in fractures with major displacement.

Necrosis (Table 3). Four months after the fracture the ^{85}Sr activity was significantly higher in cases with necrosis compared with uncomplicated healing cases. In fractures with minor displacement cases with development of necrosis had a significantly higher activity in sector I, and in the Co- and T-areas. The most intense activity was localized to the fracture region (IV). In necrosis cases with major displacement the ^{85}Sr activity increased in a specific way only in the sector IV.

Pseudarthrosis (Table 4). Pseudarthrosis occurred only in displaced fractures, and this group had the lowest activity values. In sector IV the ^{85}Sr activity was decreased by one third in pseudarthrosis cases compared to cases with uncomplicated healing.

Acetabular Activity. Four months after the fracture the activity was rather similar in fractures with different dislocations and fates. Only cases with minor displacement and development of necrosis had a significantly higher activity than those with uncomplicated healing.

Discussion

Three observations in this investigation merit comment (a) the inability of ^{85}Sr scintimetry to detect metabolic deficiency of the femoral head early after fracture, (b) the high scintimetry values at four months in cases destined for necrosis, and (c) the low values in pseudarthrosis cases.

Already in his pioneer studies of ^{32}P distribution in the upper femur in fresh fractures of the femoral neck Tucker (1950) found relatively low values in

cases destined for necrosis, and his findings were confirmed by Calandruccio (1964). A quarter century later the instant determination of femoral head vitality is becoming clinical routine with the aid of non-invasive radio-nuclide techniques (D'Ambrosia et al. 1978; Bauer et al. 1980). Why is not ^{85}Sr scintimetry diagnostic in this respect? There is no simple answer to this question which is the more baffling because $^{99\text{m}}\text{Tc}$ -labelled phosphate compounds in all other respects have given the same general bone scintimetry results as ^{85}Sr both when compared in detail experimentally (Weber et al. 1974) and in general clinical use. This difference is indeed striking; in our own laboratory nearly one half of fresh femoral neck fractures have deficient heads when measured with $^{99\text{m}}\text{Tc}$ -MDP (Bauer et al. 1982) versus none in this investigation.

The relatively high values recorded at four months in fractures destined for necrosis confirm the findings reported with similar technique by Asnis et al. (1976) and with phosphate compounds by Bauer et al. (1980).

The low values observed here in cases destined for pseudarthrosis were unexpected. In their retrospective investigation Asnis et al. (1976) did not notice this difference between necrosis and pseudarthrosis. However, the areas of interest in the present investigation were different, and Greiff (1979) reported similar low values in two cases of femoral neck pseudarthrosis; these cases were measured one year after the fracture event. The observations made here may perhaps be compared with similar reports of tibial shaft fractures; Muheim (1973) used radionuclide methods to distinguish between different fracture healing patterns. We interpret the low activity of the femoral head in pseudarthrosis cases as evidence of severe permanent vascular impairment.

References

- Asnis SE, Shoji H, Bohne WH (1976) Scintimetric evaluation of complications after femoral neck fractures. *Clin Orthop* 121: 149–156
- Bauer GCH, Wendeberg B (1959) External counting of Ca^{45} and Sr^{85} in studies of localised skeletal lesions in man. *J Bone Jt Surg* 41-B: 558–580
- Bauer G, Weber DA, Ceder L, Darte L, Egund N, Hansson LI, Strömqvist B (1980) Dynamics of technetium- $^{99\text{m}}$ methylene-diphosphonate imaging of the femoral head after hip fracture. *Clin Orthop* 152: 85–92
- Bauer G, Weber DA, Ceder L, Darte L, Egund N, Hansson LI, Strömqvist B (1982) Dynamics of post-traumatic necrosis of the femoral head studied with $^{99\text{m}}\text{Tc}$ -MDP imaging techniques. Presented as Paper at the Twenty-Eight Annual Meeting of the Orthopaedic Research Society, New Orleans, Louisiana, January 21
- Bonfiglio M, Voke EM (1968) Aseptic necrosis of the femoral head and non-union of the femoral neck. *J Bone Jt Surg* 50-A: 48–66

- Calandruccio RA (1964) The use of radioactive phosphorus to determine the viability of the femoral head. Proceedings of the Conference on Aseptic Necrosis of the Femoral Head. National Institutes of Health, pp 243-256
- Calandruccio RA, Anderson WE (1980) Post-fracture avascular necrosis of the femoral head: Correlation of experimental and clinical studies. *Clin Orthop* 152: 49-83
- Cameron B (1969) Strontium-85 Scintimetry in nontraumatic necrosis of the femoral head. *Clin Orthop* 65: 243-261
- Catto M (1976) Pathology of aseptic bone necrosis. In: Davidson JK (ed) Aseptic necrosis of bone. Excerpta Medica, Amsterdam
- Cooper A (1824) A treatise on dislocations, and on fractures of the joints, 4th edn, 1, London, Longman, Hurst, Rees, Orme, Brown and Green (eds)
- Crock HV (1980) An atlas of the arterial supply of the head and neck of the femur in man. *Clin Orthop* 152: 17-27
- D'Ambrosia RD, Shoji H, Riggins R, Stadlnik RC, De Nardo GL (1978) Scintigraphy in the diagnosis of osteonecrosis. *Clin Orthop* 130: 139-143
- Garden RS (1961) Low angle fixation in fractures of the femoral neck. *J Bone Jt Surg* 43-B: 647-663
- Graham J, Wood SK (1976) Aseptic necrosis of bone following trauma. Excerpta Medica, Amsterdam, pp 101-142
- Greiff J, Lanng S, Høilund-Carlson PF (1980) Early detection by 99m-Tc-Sn-Pyrophosphate scintigraphy of femoral head necrosis following medial femoral neck fractures. *Acta Orthop Scand* 51: 119-125
- Muheim G (1973) Assessment of fracture healing in man by serial 87m-strontium scintimetry. *Acta Orthop Scand* 44: 621-627
- Phemister DB (1930) Repair of bone in presence of aseptic necrosis resulting from fractures, transplantations and vascular obstruction. *J Bone Jt Surg* 12: 769-787
- Phemister DB (1934) Fractures of neck of femur, dislocations of hip, and obscure vascular disturbances producing aseptic necrosis of head of femur. *Surg Gynecol Obstet* 59: 415-440
- Rydell N (1964) Osteosynthesis of medial collum fractures with the "spring-loaded nail." *Acta Orthop Scand* 35: 149-157
- Santos JV (1930) Changes in the head of the femur after complete intracapsular fracture of the neck. *Arch Surg* 21: 470-530
- Sevitt S (1964) Avascular necrosis and revascularisation of the femoral head after intracapsular fractures. *J Bone Jt Surg* 46-B: 270-296
- Sevitt S, Thompson RG (1965) The distribution and anastomoses of arteries supplying the head and neck of the femur. *J Bone Jt Surg* 47-B: 560-573
- Sjöstrand LO (1974) Radionuclide scintimetry in total hip arthroplasty. Thesis, Department of Orthopaedic Surgery, Lund
- Trueta J, Harrison MHM (1953) The normal vascular anatomy of the femoral head in adult man. *J Bone Jt Surg* 35-B: 442-461
- Tucker FR (1950) The use of radioactive phosphorus in the diagnosis of avascular necrosis of the femoral head. *J Bone Jt Surg* 32-B: 100-107
- Weber DA, Keyes JW, Benedetto WJ, Wilson GA (1974) 99m-Tc pyrophosphate for diagnostic bone imaging. *Radiology* 113: 131-137

Received April 10, 1982

Tryckning
Pehr Johnson
Lund 1983.